

1 WHAT IS CLAIMED IS:
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3 1. An ink jet recording head comprising a flow passage formation substrate in which
4 pressure generation chambers communicating with nozzle openings are defined and a
5 piezoelectric element being placed on one side of said flow passage formation substrate via a
6 diaphragm and having at least a lower electrode, a piezoelectric layer, and an upper electrode,
7 comprising:

8 a compression film having a compressive stress and at least a part in a thickness
9 direction removed in at least a part of an area opposed to the pressure generation chamber,
10 thereby forming a removal part.

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12 2. The ink jet recording head as claimed in claim 1 wherein the compression film is
13 other than the piezoelectric layer.

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15 3. The ink jet recording head as claimed in claim 1, wherein the compression film has
16 at least a part in the thickness direction removed only in a portion along margins of the pressure
17 generation chamber on both sides of said piezoelectric element in a width direction thereof.

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19 4. The ink jet recording head as claimed in claim 1, wherein the compression film is a
20 conductive film being placed between the lower electrode and the piezoelectric layer and made
21 of a material substantially different from that of the lower electrode.

22
23 5. The ink jet recording head as claimed in claim 4, wherein the conductive film is a
24 film containing a second conductive film formed on the lower electrode and a first conductive
25 film formed on the second conductive film and at least the second conductive film is a film
26 made of a material different from that of the lower electrode.

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28 6. The ink jet recording head as claimed in claim 5 wherein the second conductive film
29 is a film comprising either platinum or iridium.

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31 7. The ink jet recording head as claimed in claim 5, wherein the second conductive film
32 is a metal oxide film.

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34 8. The ink jet recording head as claimed in claim 7, wherein the first conductive film is
35 a film formed of a material for preventing lead contained in the piezoelectric layer from
36 diffusing.

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38 9. The ink jet recording head as claimed in claim 7, wherein the second conductive film
39 comprises any of iridium oxide, rhenium oxide, or ruthenium oxide.

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41 10. The ink jet recording head as claimed in claim 1, wherein the compression film
42 forms at least a part of an elastic film forming at least a part of the diaphragm.

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2 11. The ink jet recording head as claimed in claim 10 wherein at least the residue of the
3 compression film forming a part of the elastic film is made of a polycrystalline substance.
4

5 12. The ink jet recording head as claimed in claim 11, wherein the elastic film is made
6 of the compression film only.
7

8 13. The ink jet recording head as claimed in claim 11, wherein the elastic film is made
9 of a film of multiple layers and at least the top layer is the compression film.
10

11 14. The ink jet recording head as claimed in claim 13, wherein the compression film
12 forming the elastic film is made of metal oxide.
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14 15. The ink jet recording head as claimed in claim 14 wherein the compression film is
15 made of zirconium oxide or hafnium oxide and has a crystal structure of a monoclinic system.
16

17 16. The ink jet recording head as claimed in claim 13, wherein a layer below the
18 compression film is a layer made of a material different from the compression film in etching
19 characteristic and is not selectively etched.
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21 17. The ink jet recording head as claimed in claim 16, wherein the not selectively
22 etched layer below the compression film is selected from metal, stabilization or partial
23 stabilization zirconium oxide, and stabilization or partial stabilization hafnium oxide.
24

25 18. The ink jet recording head as claimed in claim 10, wherein the lower electrode is
26 made of a film having a tensile stress and is thinner than the compression film of the portion
27 with at least a part removed.
28

29 19. The ink jet recording head as claimed in claim 13, wherein the elastic film contains
30 a silicon dioxide film or a boron-doped silicon film on the pressure generation chamber side.
31

32 20. The ink jet recording head as claimed in claim 1, wherein the lower electrode is
33 made of the compression film.
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35 21. The ink jet recording head as claimed in claim 20 wherein the lower electrode is
36 made of a metal material.
37

38 22. The ink jet recording head as claimed in claim 20 wherein the lower electrode is
39 made of metal oxide.
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1 23. The ink jet recording head as claimed in claim 20 wherein the lower electrode is
2 made of metal nitride.

3
4 24. The ink jet recording head as claimed in claim 20, wherein the lower electrode on
5 both sides of the piezoelectric layer in a width direction thereof is completely removed.

6
7 25. The ink jet recording head as claimed in claim 1, wherein the upper electrode is
8 formed of the compression film and is patterned together with the piezoelectric layer.

9
10 26. The ink jet recording head as claimed in claim 25 wherein the upper electrode made
11 of the compression film has a compressive stress at least after said piezoelectric element is
12 patterned.

13
14 27. The ink jet recording head as claimed in claim 26 wherein the upper electrode
15 comprises a metal material.

16
17 28. The ink jet recording head as claimed in claim 27 wherein the upper electrode made
18 of the compression film is formed by a sputtering method and a predetermined gas is added
19 into the metal material, whereby the upper electrode becomes a compressive stress.

20
21 29. The ink jet recording head as claimed in claim 28 wherein the predetermined gas is
22 an inert gas selected from helium, neon, argon, krypton, xenon, and radon.

23
24 30. The ink jet recording head as claimed in claim 27 wherein at least one additive
25 selected from metal, semimetal, semiconductor, and insulator different in constituent is added
26 into the metal material, whereby the upper electrode made of the compression film becomes a
27 compressive stress.

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29 31. The ink jet recording head as claimed in claim 30 wherein the additive is added to
30 the upper electrode by executing ion implantation.

31
32 32. The ink jet recording head as claimed in claim 30 wherein the additive is added to
33 the upper electrode by executing solid-phase diffusion from a layer placed on the upper
34 electrode.

35
36 33. The ink jet recording head as claimed in claim 32 wherein the solid-phase diffusion
37 is executed by heating in an inert gas or in vacuum.

38
39 34. The ink jet recording head as claimed in claim 25, wherein the upper electrode has
40 a first electrode formed on a surface of the piezoelectric layer and a second electrode deposited
41 on the first electrode and the second electrode is a film made of metal oxide or metal nitride.

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2 35. The ink jet recording head as claimed in claim 34 wherein the first electrode
3 comprises a metal material.

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5 36. The ink jet recording head as claimed in claim 21, wherein the metal material is
6 selected from platinum, palladium, iridium, rhodium, osmium, ruthenium, and rhenium, and
7 compounds thereof.

8
9 37. The ink jet recording head as claimed in claim 14, wherein the metal oxide is
10 selected from ruthenium oxide, indium oxide tin, cadmium indium oxide, tin oxide, manganese
11 oxide, rhenium oxide, iridium oxide, strontium ruthenium oxide, indium oxide, zinc oxide,
12 titanium oxide, zirconium oxide, tantalum oxide, hafnium oxide, osmium oxide, rhodium oxide,
13 palladium oxide, and molybdenum oxide, and compounds thereof.

14
15 38. The ink jet recording head as claimed in claim 23, wherein the metal nitride is
16 selected from titanium nitride, niobium nitride, zirconium nitride, tungsten nitride, hafnium
17 nitride, molybdenum nitride, tantalum nitride, chromium nitride, and palladium nitride, and
18 compounds thereof.

19
20 39. The ink jet recording head as claimed in claim 37, wherein layers formed of the
21 metal oxide and the metal nitride are formed by oxidation or nitriding after film formation.

22
23 40. The ink jet recording head as claimed in claim 1, wherein the elastic film forming at least a
24 part of the diaphragm has at least a part in a thickness direction removed in an area which is
25 opposed to the pressure generation chamber and is other than the piezoelectric layer.

26
27 41. The ink jet recording head as claimed in claim 40 wherein the elastic film has at
28 least a part in the thickness direction removed only in a portion along the margins of the
29 pressure generation chamber on both sides of said piezoelectric element in the width direction
30 thereof.

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32 42. The ink jet recording head as claimed in claim 40, wherein said piezoelectric
33 element is formed on the elastic film so as to extend to the portion with at least a part of the
34 elastic film removed.

35
36 43. The ink jet recording head as claimed in claim 42 wherein the piezoelectric layer
37 forming said piezoelectric element is roughly uniformly thick.

38
39 44. The ink jet recording head as claimed in claim 42 wherein an end of the extension
40 of the piezoelectric layer forming said piezoelectric element to the portion with the part of the
41 elastic film removed is thicker than other portions.

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2 45. The ink jet recording head as claimed in claim 40, wherein at least a part of the
3 piezoelectric layer is formed across an area opposed to the pressure generation chamber and
4 said piezoelectric element is formed by patterning only the upper electrode or the upper
5 electrode and a part of the piezoelectric layer in a thickness direction thereof.

6
7 46. The ink jet recording head as claimed in claim 40, wherein the lower electrode is
8 placed uniformly in an area opposed to said piezoelectric element and in other areas.
9

10 47. The ink jet recording head as claimed in claim 1, wherein the diaphragm is
11 deformed convex outwardly from the pressure generation chamber.
12

13 48. The ink jet recording head as claimed in claim 1, wherein a stress of the
14 piezoelectric layer when a drive force load is imposed on said piezoelectric element is equal to
15 a stress at the piezoelectric layer formation time or is larger in a tension direction.
16

17 49. The ink jet recording head as claimed in claim 48 wherein said piezoelectric
18 element in the area opposed to the pressure generation chamber is bent convex to the
19 piezoelectric layer side when the pressure generation chamber is formed.
20

21 50. The ink jet recording head as claimed in claim 48, wherein an expansion force of a
22 portion of the diaphragm opposed to said piezoelectric element in the area opposed to the
23 pressure generation chamber is relatively smaller to the compression side than an expansion
24 force in other than the area opposed to said piezoelectric element.
25

26 51. The ink jet recording head as claimed in any one of claims 1 to 50 wherein the
27 pressure generation chambers are formed on a silicon monocrystalline substrate by anisotropic
28 etching and the layers of said piezoelectric element are formed by film forming and
29 lithography process.
30

31 52. An ink jet recorder comprising an ink jet recording head as claimed in any one of
32 claims 1 to 50.
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34 53. The ink jet recording head as claimed in claim 1, wherein said compression film is
35 an elastic film and said lower electrode film is formed uniformly on said elastic film without
36 patterning.
37

38 54. The ink jet recording head as claimed in claim 1, wherein ends of said piezoelectric
39 element are extended to an area opposite to said removal part.
40

1 55. The ink jet recording head as claimed in claim 1, wherein said first electrode is said
2 compression film.

3
4 56. A method of making an ink jet recording head having a flow passage formation
5 substrate comprising the steps of:

6 forming an elastic film having a compressive stress on said flow passage formation
7 substrate;

8 forming a first electrode film on said elastic film;

9 forming a piezoelectric film on said electrode film;

10 forming a second electrode film on said piezoelectric film;

11 etching said second electrode film, said piezoelectric film, and said first electrode film
12 to form a piezoelectric part; and

13 overetching said elastic film in the thickness direction to form elastic film removal
14 parts.

15
16 57. The method of claim 56, wherein said piezoelectric film, said first electrode film,
17 and said second electrode film are under tension before said etching step.

18
19 58. The method of claim 57, wherein said etching step and said overetching step are
20 performed so that tensile stresses released during said etching step balance with a compressive
21 stress released during said overetching step.

22
23 59. The method of claim 58, wherein said elastic film comprises at least 2 layers.

24
25 60. A method of making an ink jet recording head having a flow passage formation
26 substrate and pressure generating chambers formed therein comprising the steps of:

27 forming a compressive film having a compressive stress on said flow passage
28 formation substrate;

29 overetching said compressive film in the thickness direction to form elastic film
30 removal parts;

31 forming a lower electrode film on said overetched compressive film;

32 forming a piezoelectric active part on said lower electrode film.

33
34 61. The method of claim 60, wherein said piezoelectric active part includes a
35 piezoelectric film formed over substantially all of said flow passage formation substrate and an
36 upper electrode film formed on said piezoelectric film.

37
38 62. The method of claim 56, further including the steps of:

39 extending said piezoelectric active part in the width direction to an area opposed to said
40 elastic film removal part.

1 63. A method of making an ink jet recording head having a flow passage formation
2 substrate comprising the steps of:

3 forming an compressive film having a compressive stress on said flow passage
4 formation substrate;

5 forming a piezoelectric part; and

6 overetching said compressive film in the thickness direction to form elastic film
7 removal parts.

8
9 64. The ink jet recording head as claimed in claim 4, wherein said conductive film is a
10 metal oxide film.

11
12 65. The ink jet recording head as claimed in claim 4, wherein said conductive film is a
13 film formed of a material for preventing lead contained in the piezoelectric layer from diffusing.

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15 66. The ink jet recording head as claimed in claim 65, wherein said material for
16 preventing lead contained in the piezoelectric layer from diffusing is selected from iridium,
17 iridium oxide, ruthenium oxide and rhenium oxide.

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